

TITLE: Cotton breeding in French-speaking Africa: Milestones and prospects

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ABBREVIATIONS: +b (yellowness without unit); CAR (Central African Republic); E1
(elongation at breakage in %); ha (hectares); H1BF (number of nodes
between the cotyledonary node, scored 0, and the node bearing the first
developed fruiting branch); Hs (standard fineness in mtex); HVI (high
volume instrument); GOT (ginning outturn in %); MI (micronaire without
unit); PM (percentage of mature fibres); R1/RT (percentage of the first
seed cotton harvest relative to the total harvest); Rd (reflectance or
brightness in %); SL2.5 (span length 2.5%: length exceeded by 2.5% of the
longest fibres by number in mm); T1 (tenacity or strength in g/tex); UHML
(upper half mean length in mm); UR (uniformity ratio in % =
 $SL2.5 \times 100 / SL50$)

ABSTRACT

When cotton breeding programmes were first set up in French-speaking Africa in 1946, breeders were already taking the needs of different cotton stakeholders into account. The main breeding targets were productivity, resistance to pests and major cotton diseases, ginning outturn and fibre quality. The aim of this paper is to demonstrate how breeding has enhanced the performance of African cotton subsectors through presentation of results and experimental data from multilocation trials. Briefly, breeders have focused on *Gossypium hirsutum* cultivars, thus giving rise to plants with a relatively long growth cycle, that are vegetative and very floriferous, with delayed boll ripening (facilitating manual harvest), with a capacity to adapt to biotic and abiotic stress conditions, and with resistance to bacteriosis. Substantial gains were achieved in terms of productivity, ginning outturn and fibre quality (length, tenacity, fineness, and colorimetry). More than 90 cotton cultivars have been bred and released over a 60-year period. Genetic progress has, however, been limited in the last decade and African breeders will have to adopt new technologies to achieve further improvement in important traits.

Key words: cotton, breeding, French-speaking Africa, cultivar

Introduction

Cotton is the only crop that provides farmers in African savanna regions with a guaranteed income. It is cultivated by some two million smallholders on plots with an area of generally less than a hectare. Cotton provides a lifeline for more than 12 million people in French-speaking Africa—the second-ranking cotton fibre exporting region in the world (1 million mt of fibre in 2006, or 11% of the total world trade volume) after USA. Export income was around a billion euros in 2006, representing 50-90% of the total export income of some countries like Mali, Burkina Faso, Benin or Chad. Cotton breeding underlies this African success story. Immediately after the first breeding programmes were set up in Africa, cotton research institutions focused on addressing the needs of all stakeholders in this subsector, especially smallholders striving to improve cotton productivity with the least possible risk, but also ginneries wanting to boost their ginning outturn and spinners seeking better quality fibre. We will review the history of cotton breeding in French-speaking Africa, while assessing the genetic progress achieved and discussing prospects for the future.

1. Breeding history and features of African cotton cultivars

Cotton breeding first began in 1946 in Côte d'Ivoire (Bouaké station), the Central African Republic (Bossangoa and Bambari stations), and Chad (Tikem and Bebedjia stations), and this work was extended subsequently to other countries, including Mali (N'Tarla-M'Pesoba) and Togo (Anié-Mono) in 1947, Madagascar (Tuléar, Samangoky and Majunga) and Cameroon

(Maroua) in 1959, Senegal (Kaolak and Tambacounda) as of 1969, Burkina Faso (Farako-ba) as of 1980, and finally Benin (Parakou) in 1998.

In 1946, researchers initiated breeding programmes to obtain improved cultivars adapted to African ecological and cropping conditions. At that time, different cotton species and populations were being grown throughout the continent, including *Gossypium barbadense* (Ishan types from Nigeria or Mono from Togo) and *G. hirsutum* (Allen, N'kourala and Triumph cultivars). Breeders were faced with the problem of determining the best adapted species to grow under African environmental conditions. Pesticides were not yet being applied, so *G. barbadense* (Mono cultivar), which is naturally highly resistant to boll worms, prevailed in areas where parasite pressure was highest, i.e., along forest edges (Benin, Togo, central Côte d'Ivoire). In Central Africa (Oubangui Chari, Chad, and Cameroon) and in savanna areas (Upper Volta, French Sudan), scientists promoted *G. hirsutum* genotypes that were bacteriosis-resistant (Allen or N'kourala) or that had a high ginning outturn (Triumph).

In the mid-1950s, with the advent of DDT, *G. hirsutum* cultivars definitively prevailed over *G. barbadense* types, which were less productive, had a longer production cycle and irregular productivity. Farmers continued to grow this latter species only in Togo up until the early 1970s.

Geneticists soon favoured a particular type of cotton plants, which had quite high vegetative growth, were very floriferous, and had relatively long growth cycles. The boll shedding rate was high, but staggered manual harvesting was facilitated by the fact that production build-up was a gradual process. This cotton type was especially interesting for its capacity to tolerate biotic stress (pests, diseases) and abiotic stress (drought).

The leaf and stem hairiness trait was soon found to provide effective protection against jassids, i.e., sucking insects that attack plants at the onset of vegetative growth, and bacteriosis resistance was then obtained by utilising Allen and N'kourala germplasm. Bolls were small, which was correlated with the high number of flowers produced, with small seeds, thus enabling high ginning outturn.

During the independence period (1960), cotton growing was the only agricultural resource that generated income for farmers in savanna areas. A major boom in cotton production thus occurred, backed by the new African states. The introduction of animal draught, pesticides, early sowing, along with breeding, helped to significantly increase cotton productivity and cost-effectiveness of the crop, while modernising agricultural conditions. From 1960 to 1980, there was a considerable increase in yields, from 199 kg ha⁻¹ of seed cotton in 1961 to 914 kg ha⁻¹ in 1991 (B. Hau, 1994). This increase was due to a combination of crop management factors, including genetic advances. Breeding initiatives likely accounted for around a third of the productivity increase achieved over this decade (Hau, 1988; Meritan et al., 1993).

In the mid-1970s, pyrethroid insecticides further enhanced cotton productivity. With this innovation, early sowing could be implemented, as young bolls, which are highly susceptible to bollworm infestation, were better preserved. Breeders thus focused on shortening the cotton growth cycle.

2. Cultivar renewal and genetic progress

2.1. Cultivar renewal

In 60 years, 90 different genotypes obtained through breeding initiatives at African research stations were released to smallholders in French-speaking Africa (Table 1). In addition, 10 other cultivars were imported from foreign countries. Cultivars bred during each period have marked the history of African cotton cropping. An average of 1.5 cultivars has been bred yearly over this period, but a higher number of new cultivars were obtained during certain periods. Over this 60-year period, the mean cropping lifespan of a cotton cultivar was 8 years, with some cultivars being withdrawn soon after their release, while others were cropped for longer time periods (BJA 592 holds the cropping longevity record of 22 years). For a given year, the mean age of a cultivated variety was around 5.5 years.

The main cultivars cropped for at least 10 years are shown in Table 1. Most of these cultivars were widely distributed, ranging from Senegal to the Central African Republic. This highlights that an African cultivar can be successfully bred at one site and then cropped at another site, since the climatic conditions are relatively similar between countries, i.e., temperature, rainfall. The most commonly cropped cultivars were ISA 205 (4.3 million ha over a 15-year cropping period), N'TA 88-6 (2.9 million ha over 13 years), STAM F (2.8 million ha over 17 years), BJA 592 and derivative cultivars (2.3 million ha over 22 years—the longest cropping period), STAM 18A (2.3 million ha over 11 years), IRMA 96+97 (2.2 million ha over 14 years) and STAM 59A (2.2 million ha over 10 years).

2.2. Genetic progress

150 It is not an easy task to determine the extent to which genetic progress has enhanced the
151 performance of cotton subsectors. Table 2 shows progression patterns of these performances on
152 the basis of 10-year means since the beginning of the independence period. These statistics
153 highlight progress in the uncorrected results achieved by cotton subsectors in the 10 main
154 French-speaking African countries. Cotton productivity and ginning outturn sharply increased
155 over the first three decades during which the cropping area expanded. Genetic progress has
156 slowed since the early 1990s, possibly because some limits had been reached in terms of utilising
157 the available variability, but also likely due to the drastic reduction in genetic research funding.
158 Cotton yields still remained quite stable despite the marked increase in cropping area and
159 structural changes in cotton subsectors, thus confirming the hardiness and robustness of currently
160 cropped cultivars.

161
162 The increase in cotton yields could be explained jointly by the improvement in the
163 production potential of cultivars, progress in farmers' agricultural practices, and the increase in
164 pesticide treatment efficacy. The extent of involvement of different crop management factors
165 governing the genetic potential of cultivars must be accurately assessed to determine the extent to
166 which genetic progress has improved the performances of cotton subsectors. Meritan *et al.*
167 (1993) assessed production potential patterns to compare differences between paired cultivars, in
168 multilocation cultivar trials in Cameroon. The authors concluded that modern cultivars (i.e.,
169 IRMA 1243) produced 145% more than the initially cultivated cultivar (Allen Commun) in the
170 extreme northern province and 130% more in the northern province. In Côte d'Ivoire, Hau (1988)
171 also noted a production increase of around 30% in comparisons of paired cotton cultivars in
172 multilocation experimental trials conducted between 1950 and 1980.

Genetic improvement could be the main factor to explain the increase in ginning outturn. Changes in this trait were clearly shown in national ginning mill production results. Graph 1 shows ginning outturn patterns in seven African countries from 1951 to the present. This increase in ginning outturn is clearly the result of successful African cotton breeding initiatives. This parameter, which is usually negatively correlated with seed index and fibre length, has gradually changed by maintaining seed size and enhancing the fibre length, thus modifying the genetic correlations between both traits. Note that ginning outturn very quickly increased when cotton breeding first began, but it has now levelled off. This trait is quite susceptible to environmental conditions, and levels are much higher in some countries like Côte d'Ivoire than in others, even with the same cultivars.

African cotton cultivars have a relatively long vegetative cycle. However, over time the cropping cycle of the selected cultivar types remained slightly shorter than that of the initially cultivated cultivars. The data presented in Table 3 quantify this phenomenon—the first flower opening date and the first boll opening date occurred around 10 and 15 days, respectively, earlier in IRMA D 742 than in Allen Commun. The decline in the number of nodes between the cotyledonary node and the node bearing the first developed fruiting branch (H1BF), which correlates with the production earliness, accounts for this phenomenon, as also does the R1/RT parameter (Bednarz and Nichols, 2005). This could be an adaptation to the slightly shorter rainy season than in the past, however, this earliness is more likely an indirect result of improvements in pest control techniques, such that bolls formed on plants are less threatened by pests.

It is harder to monitor variations in fibre traits because fibre quality assessment techniques

have changed over the years (Halo, SL2.5, UHML for fibre length, Pressley, stelometer, HVI for strength, etc.). Table 4 presents technological results for the primary cultivars cropped in Africa since the 1950s. These data were not obtained in a single trial, but they still highlight the genetic progress that affected all fibre quality parameters.

In 60 years, cotton fibre length increased, fineness improved, tenacity improved by 4 g tex^{-1} (stelometer, current tenacities are equivalent to a standard HVI level of 28/30 g tex^{-1}) and the colorimetry parameters have been enhanced (brightness and yellowness indices). Genetic progress is slow because many sometimes negatively correlated genes are involved. Moreover, it is also essential to pool a well balanced set of traits in the same genotype—a substantial task. The negative correlations between these parameters (ginning outturn/fibre length, tenacity/elongation, maturity/fineness, etc.) (Meredith, 1984; Lançon et al., 1993) are being gradually overcome.

3. Prospects

3.1. Improvement in the production potential of cotton cultivars

Over the last 10 years, cotton production has more than doubled in French-speaking Africa, but mean yields have not increased at the same rate as in previous decades. This may not be unexpected since logic dictates that the production potential of any crop commodity cannot continue increasing at the same pace as it did in the past—obviously a ceiling is reached at one point. The fact that this production potential remained stable at the time when the cropping area increased by almost twofold, input subsidies were withdrawn, and supervisory services and research were decreased indicates that the cultivars being cropped are highly robust and hardy.

The mean fibre yield in French-speaking Africa is 440 kg ha⁻¹, which is one of the best levels worldwide under rainfed cropping conditions. Scientists must now seek to determine whether further progress is possible.

Sixty years of cotton improvement initiatives have enabled geneticists to obtain a morphotype that is well adapted to African environmental and cultivation conditions—*G. hirsutum* is a relatively tall plant with substantial vegetative growth and highly floriferous but can be marked by substantial blossom drop, which has the advantage of enabling staggered boll ripening (important for manual harvesting), and this cotton plant is also physiologically able to efficiently tolerate different stresses. In rainfed conditions, the plant can thus offset or tolerate the effects of climatic variations. The production build-up phase of these cultivars is quite slow, so they have a relatively long growth cycle. Hence, they can fully express their production potential when the crop is sown at an early date. Early sowing could therefore be recommended, but most bolls will form just at the time when parasite pressure is highest, so efficient pesticide treatments are essential. When the rainy season is slightly longer than normal, these cultivars can restart a small production of new bolls at the top of the plant after cutout.

However, these cultivars and cultivar type may no longer be suitable because of the constraints facing farmers are changing because of the shortening of the rainy season in the southernmost areas, and the cropping schedule cannot always comply with cotton planting date limits (semi-late crops) because food crop needs which obviously take precedent. In both cases, cultivars with a shorter cycle could enable farmers to continue cultivating areas under low and variable rainfall conditions or to increase the cotton cropping area at sites where semi-late crops are still profitable.

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243 **3.2. Genetically-modified cotton cultivars**

244 The imminent arrival of transgenic plants on the world agricultural scene will completely alter
245 cotton breeding programmes. These new cultivars, which are resistant to pest insects, are very
246 attractive, thus warranting the extent of the research devoted to them. This research is, however,
247 very costly and the technology patents are highly complex, so it is hard for African research
248 centres to adopt and implement them. Concerns of farmers in developing countries should be
249 taken into greater account, while ensuring that new products will enable sustainable
250 environment-friendly innovations. Farmers are mainly interested in adopting GM technology to
251 reduce cropping risks and increase their income. The technology should be affordable for African
252 smallholders. Moreover, in these areas, cotton pest conditions are often unique and complex,
253 which is sometimes out of line with the strategies promoted by large-scale pesticide
254 manufacturers.

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257 **3.3. Improvement in cotton fibre technological qualities**

258 Conventional breeding programmes are still focused on improving cotton technological traits.
259 Marker-assisted selection has given rise to products with more enhanced technological features
260 (cotton fibres are longer and finer, with higher tenacity). These innovations should now be
261 assessed and tested to further improve the performance and sustainability of future cotton crops.

262

263

264 **Conclusion**

265
266 Many cotton cultivars developed by CIRAD in collaboration with African partners currently are
267 being grown on an area of around two million ha every year by farmers in tropical African
268 savanna regions. Substantial productivity, ginning outturn and fibre technological quality (length,
269 tenacity, and fineness) gains have been achieved over the last 60 years. This has prompted a
270 boom in African cotton production to the extent that French-speaking African countries
271 collectively represent the second-ranking cotton exporter in the world. Although there has been a
272 production slowdown in the last decade, the use of new technologies should ultimately lead to
273 further improvements, but these will be increasingly expensive and hard to achieve.

274 In the last 10 years, the scientific, economic, and social setting has changed considerably
275 worldwide. By striving to effectively manage new technologies, remaining creative and attentive
276 to the farming community, cotton breeding will continue to help African countries develop their
277 genetic research, while promoting cotton cropping to the benefit of farmers.

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301 **Table 1:** Cotton cultivar dissemination pattern in Africa from 1960 to present

Breeding period	Number of new cultivars released	Mean cropping lifespan of cultivars (years)	Mean age of cultivars (years)	Cultivars with a cropping lifespan of over 10 years
1961-1970	5	11	5.0	Reba B50, BJA 592, HAR 444-2
1971-1980	14	8	5.8	L299-10, L142-9, SR1F4, IRCO 5028, MK73, B163
1981-1990	20	8	5.9	IRMA 96+97, ISA 205, IRMA 1243, STAM F, GL7, STAM 42
1991-2000	31	7	4.7	F135, IRMA 772, N'TA 88-6, STAM 18A, STAM 59A, IRMA BLT-PF
2001-2005	3		5.9	not applicable

302

303 **Table 2:** Statistical data on cotton subsector performance (annual means)

Criteria	periods					
	1951-1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2006
Cropping area (1000 ha)	387	668	779	916	1701	2246
Seed cotton production (1000 t)	111	273	512	971	1590	2336
Fibre production (1000 t)	35	102	194	396	717	996
Ginning outturn (%)	31.9	36.6	38.1	39.6	41.8	42.0
Seed cotton yield (kg/ha)	290	398	660	1054	951	1039
Fibre yield (kg/ha)	88	149	250	427	424	443

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305 **Table 3:** Earliness patterns in cotton crops in Cameroon

Cultivar	1 st flower date	1 st boll date	R1/RT	H1BF
Allen commun	61	114	14	5.6
Allen 333	59	111	29	6.4
BJA 592	61	114	19	5.9
L 142-9	59	109	40	6.0
IRCO 5028	61	111	30	5.3
IRMA A 1239	52	101	47	4.0
IRMA D 742	51	95	64	4.0

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307 **Table 4:** Technological features of 12 cultivars most commonly cropped over the 1959-2006 period

	date of 1 st release	GOT (%)	SL2.5 (mm)	UR (%)	MI	PM (%)	Hs (mtex)	T1 (g tex ⁻¹)	E1 (%)	Rd (%)	+b
Allen 333	1959	38.1	27.8	46.8	3.95	78.7	200	18.4	5.6	71.8	10.7
Reba B50	1964	36.9	27.2	48.6	4.40	76.2	227	17.2	5.3	70.5	10.0
BJA 592	1965	37.3	27.7	46.8	4.07	75.2	250	19.6	5.3	75.7	9.6
IRCO 5028	1973	39.7	27.5	48.2	4.32	76.0	208	20.1	6.8	75.7	9.5
IRMA 96+97	1982	41.6	28.6	44.9	4.08	78.9	211	21.1	5.7	74.8	10.0
ISA 205	1983	43.7	29.1	46.7	3.81	80.2	168	21.3	6.1	74.6	10.5
STAM F	1987	42.5	28.2	47.1	4.00	79.4	184	21.2	6.2	76.0	9.4
STAM 42	1990	42.9	28.0	47.9	3.91	76.5	189	21.2	5.9	75.4	10.4
STAM 18A	1994	43.4	29.8	47.0	3.72	79.2	172	23.1	6.3	75.9	9.5
FK 290	1996	42.7	30.3	48.9	3.61	78.7	165	24.1	5.7	75.9	10.4
STAM 279A	1997	43.2	28.7	47.1	3.89	80.0	179	23.3	6.2	76.1	9.2
A 51	1997	41.9	29.9	46.5	3.82	75.0	160	21.4	5.7	75.6	9.2

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309

310 **Graph 1:** Ginning outturn patterns from 1951 to present

